

**Lidar measurements of tropospheric and stratospheric ozone at Table Mountain Facility, California, and Mauna Loa Observatory, Hawaii:
An overview of 10 years of measurements.**

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Abstract

As part of the Network for Detection of Stratospheric Change (NDSC) three lidars are currently operated by the Jet Propulsion Laboratory (JPL). These systems provide high-resolution vertical profiles of tropospheric and stratospheric ozone and aerosols, and stratospheric and mesospheric temperature, at the JPL-Table Mountain Facility, California (TMF, 34.4°N, 117.7°W), and at the Mauna Loa Observatory (MLO, 19.5°N, 155.6°W).

The original differential absorption lidar system (DIAL) located at TMF has been measuring ozone number density from ~18-50 km and temperature from ~30-75 km, on several nights a week between 1988 and 1999. This system is being upgraded to include Raman scattered channels and to extend the altitude range of the measurements. The profiles obtained by this system since 1988 have allowed investigation of the day-to-day, seasonal, and interannual variability of stratospheric ozone at TMF. The vertical structure shows a clear annual cycle in opposite phase below and above the ozone concentration peak, typical of mid- to subtropical latitudes. High day-to-day variability is also observed in the lower stratosphere, revealing the various effects of the dynamics (laminated structures, tropopause variability, etc.).

A similar stratospheric DIAL system was installed at MLO, Hawaii, in July 1993. This system is using 2 pairs of Rayleigh/Mie channels similarly to the TMF system, and an additional pair of vibrational-Raman channels, allowing ozone, aerosol, and temperature measurements in the lowermost stratosphere (down to 15 km). The profiles obtained since 1993 have also allowed the ozone vertical structure above MLO to be studied. As expected for tropical latitudes the observed ozone concentration tends to be higher during the summer months and lower during the winter months throughout the entire stratospheric ozone layer. A weak signature of the extra-tropical latitudes is observed near 19-20 km in late winter. Large variability has been observed in the lowermost stratosphere, probably connected with the tropical tropopause variability. The ozone Quasi-Biennial Oscillation (QBO), and El Nino and the Southern Oscillation (ENSO) is currently being investigated.

A new tropospheric system has been recently developed at TMF, providing high-resolution ozone profiles between 5-17 km. The combined results of the tropospheric and stratospheric systems will eventually lead to accurate ozone measurements in a wide 5-55 km range.

An overview of these instruments with emphasis on the atmospheric profiles obtained will be presented.

DIAL ozone lidars:

- 2 laser radiations emitted into the atmosphere
- Stratospheric systems (TMF and MLO)
 - 308 nm weakly absorbed by ozone and 353 nm non-absorbed by ozone
 - MLO only: Also use of vibrational Raman scattering (returned wavelengths 331 nm and 385 nm) to minimize the polluting effects of the stratospheric aerosols.
- Tropospheric system (TMF):
 - 289 nm strongly absorbed by ozone and 299 nm moderately absorbed
- Light is Rayleigh backscattered by the air molecules
- The two returned signal slopes are compared to deduce ozone number density
- Main signal corrections: background noise, saturation effects, Rayleigh extinction.

Datasets:

Stratospheric systems (figure 1):

- TMF: >1000 early night ozone (18-50 km) and temperature profiles (25-85 km) since 1988
- MLO: >800 early night ozone (15-55 km) and temperature profiles (15-85 km) since 1993
- 300 m vertical resolution (600 m for TMF before September 1994)
- Meas. at TMF only above 25-30 km when high volcanic aerosol content, e.g. after Pinatubo
- Instrumental error at ozone peak levels: 1-5%
- Instrumental error at bottom of profiles: 10-15%
- Instrumental error at top of ozone profiles: >30% for altitudes >45 km
- Temperature error at bottom of temperature profiles: <1%
- Temperature error at top of temperature profiles: 15%

Tropospheric system:

- 50 afternoon, evening and early night ozone profiles (5-20 km) since November 1999
- 60 m vertical resolution (can be set to different values if necessary)
- Instrumental error in free troposphere: 1-5%
- Instrumental error in lower stratosphere (top of profile): 10-30%
- Instrumental error at tropopause: <10%

Figure 2: middle atmospheric temperature climatology over the period 1989-1998 for TMF and 1993-1998 for MLO

- Stratospheric and mesospheric temperatures at TMF typical of mid- to subtropical latitudes:
 - Warm winter mesosphere cold summer mesosphere
 - Cold winter stratosphere and warm summer stratosphere
 - Annual cycle is dominant with a weak semiannual signature
- Stratospheric and mesospheric temperatures at MLO typical of northern tropical latitudes:

Mixed semiannual and annual cycles (northern hemisphere)
Semiannual cycle is dominant with an annual signature especially in spring

Figure 3: Two typical stratospheric ozone number density profiles at TMF with their associated error bars (1σ)

- Stratospheric ozone peak lower (22 km) and stronger ($5.5 \cdot 10^{12} \text{ cm}^{-3}$) in winter/spring (blue profile)
- Summer peak higher (25-26 km) and weaker ($4.5 \cdot 10^{12} \text{ cm}^{-3}$) (orange profile)
- Large vertical structures in the winter/spring profile: ozone laminae

Figure 4: Two typical stratospheric ozone number density profiles at MLO with their associated error bars (1σ)

- Stratospheric ozone peak near 24-25 km all year round
- Almost no seasonal variation in the ozone peak altitude and strength ($4\text{-}5 \cdot 10^{12} \text{ cm}^{-3}$ at 24-26 km)

Figure 5: Seasonal variation (%) of stratospheric ozone at TMF at 2 different altitudes.

- Annual cycle clearly seen and opposite at 21 km and 30 km
 - Out-of-phase transition at the altitude of the ozone peak (22-26 km) (not shown)
 - Ozone more abundant in winter in the lower stratosphere (below ozone peak)
 - Ozone more abundant in summer above the ozone peak.
- => Seasonal cycle at TMF typical of mid- to subtropical latitudes

Figure 6: Seasonal variation (DU) of stratospheric ozone column at TMF between 20 km and 55 km.

- Maximum in summer, minimum in winter
- => Small effect of 20-22 km layer

Figure 7: Tropospheric ozone profiles on March 19, 21, 22, and 23, 2000 during the polar vortex filament event of March 21-22, 2000 over TMF.

- Ozone above and below tropopause clearly increased during the passing filament.
 - Max ozone concentration could not be measured because filament passed over TMF at midday
- => key information for ozone transport in lower stratosphere from high to low latitude

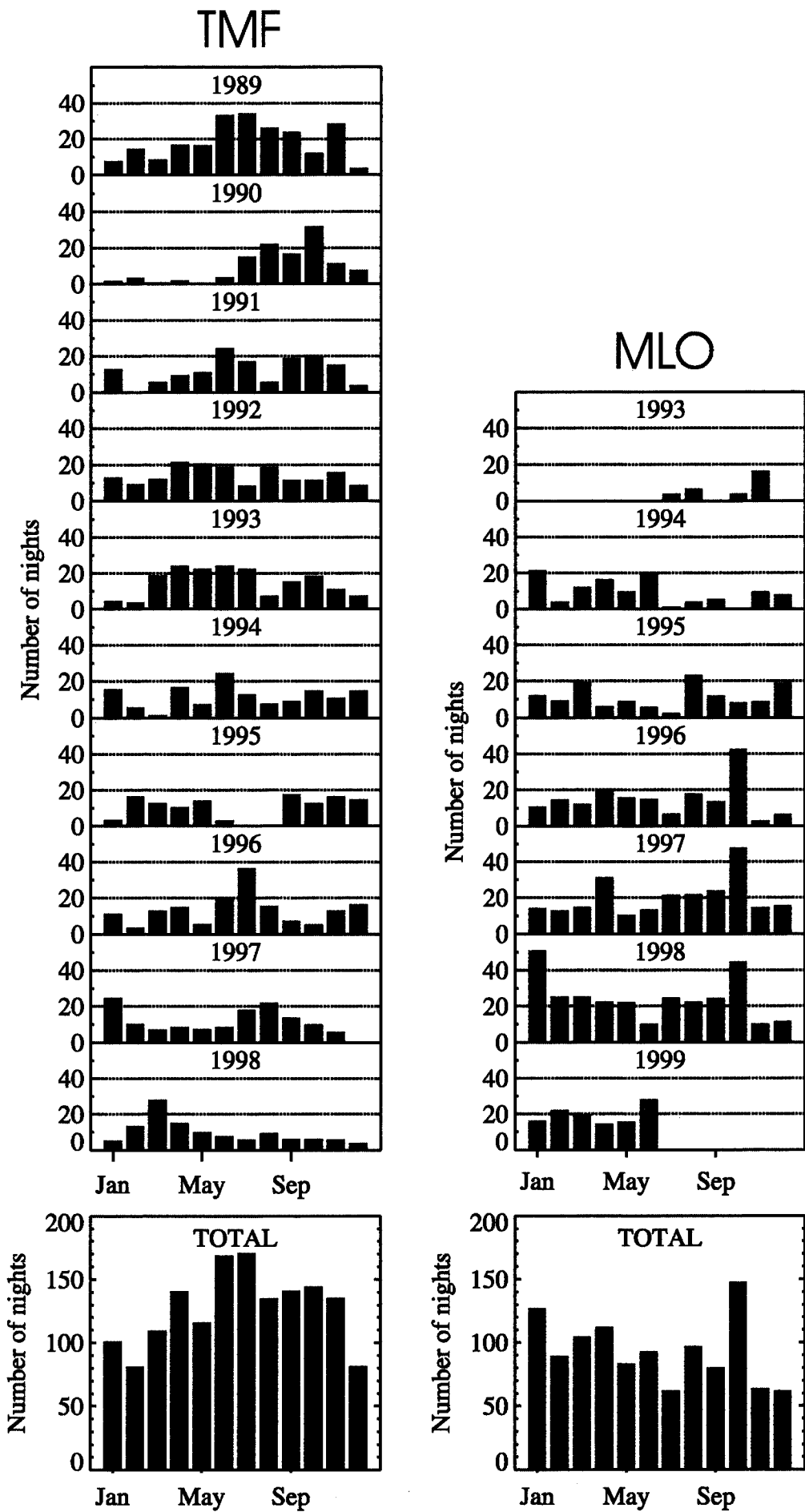


Figure 1

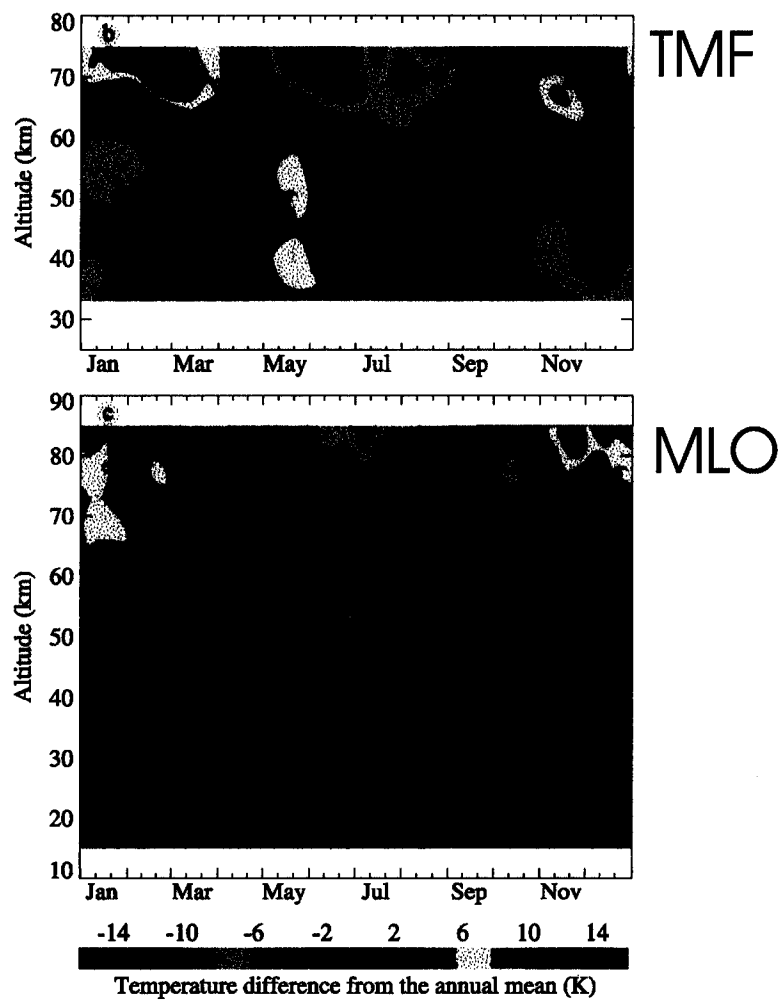


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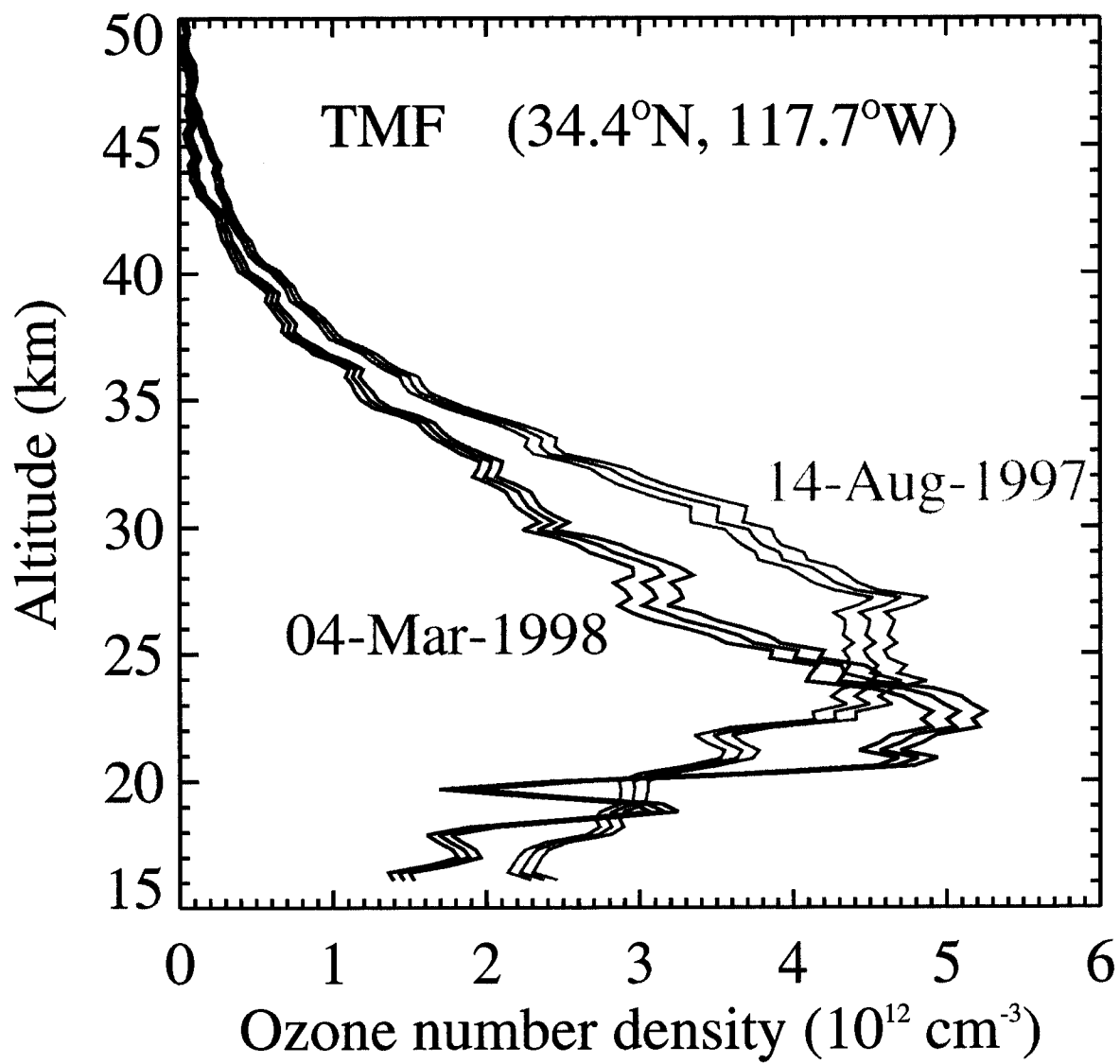


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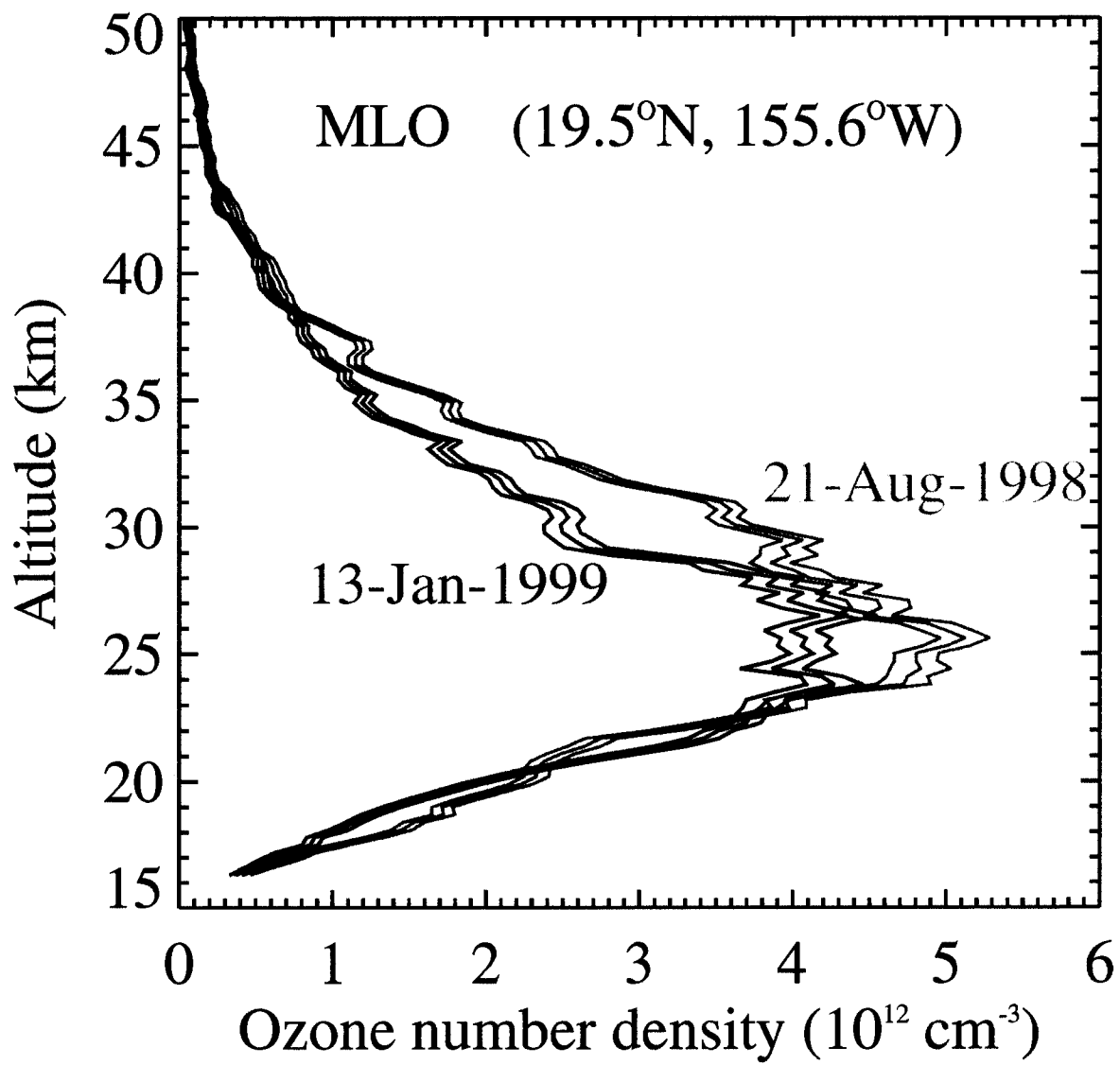


Figure 4

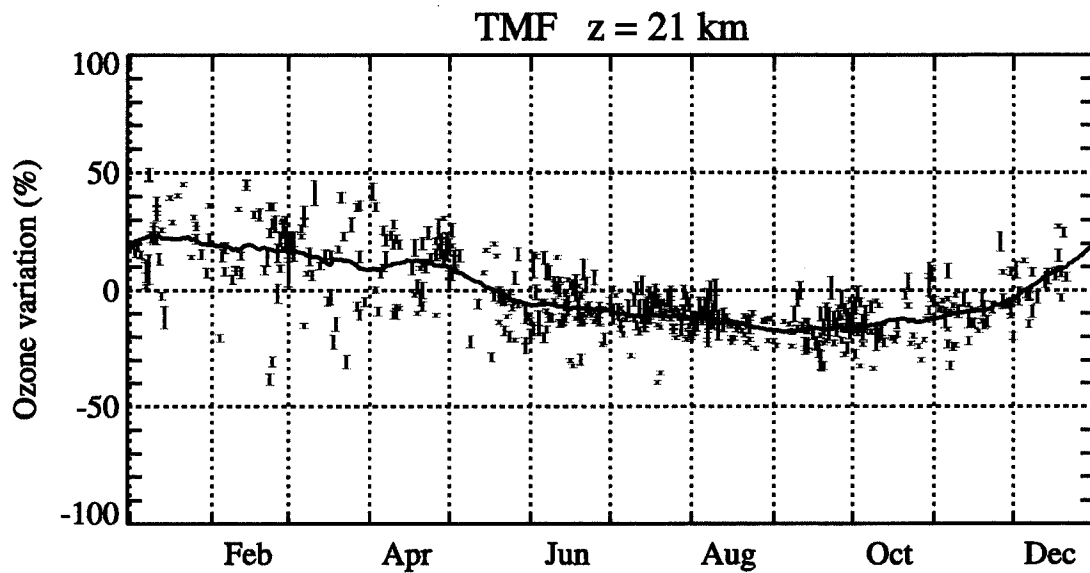
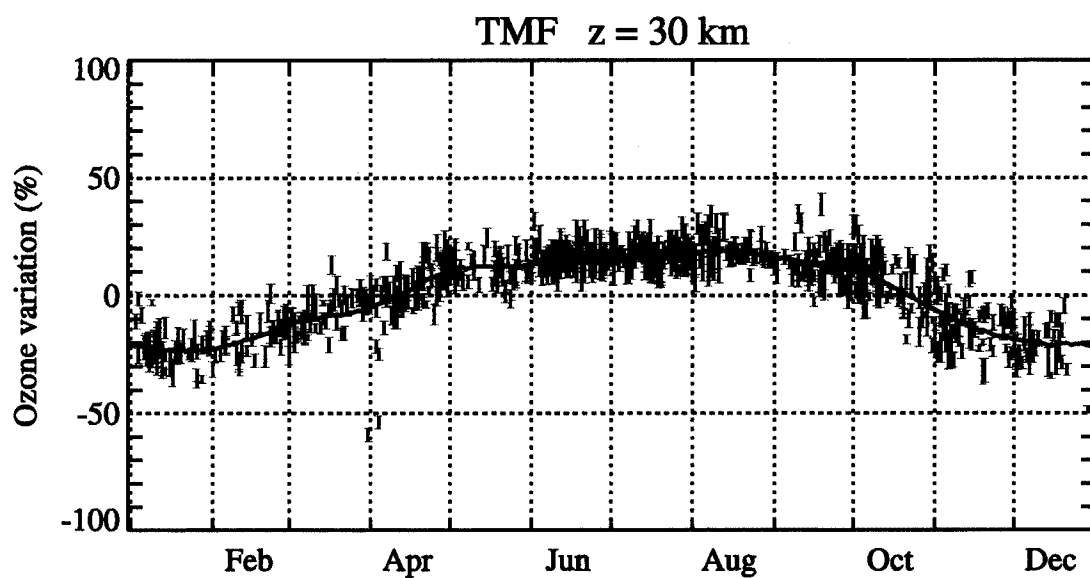


Figure 5

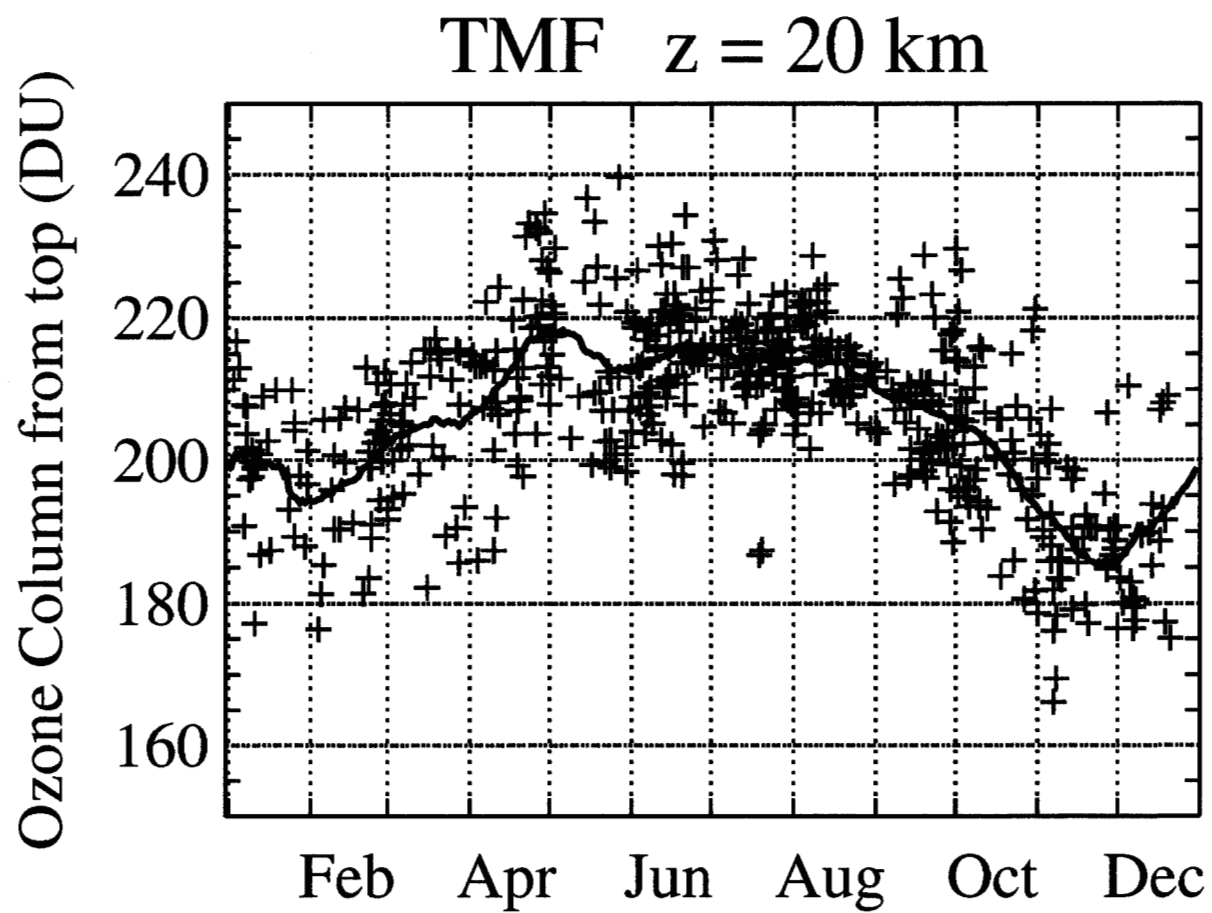


Figure 6

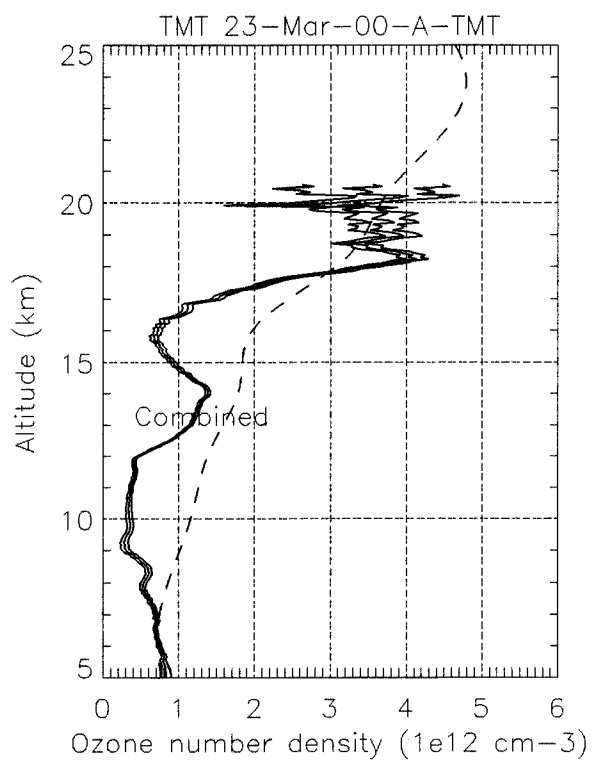
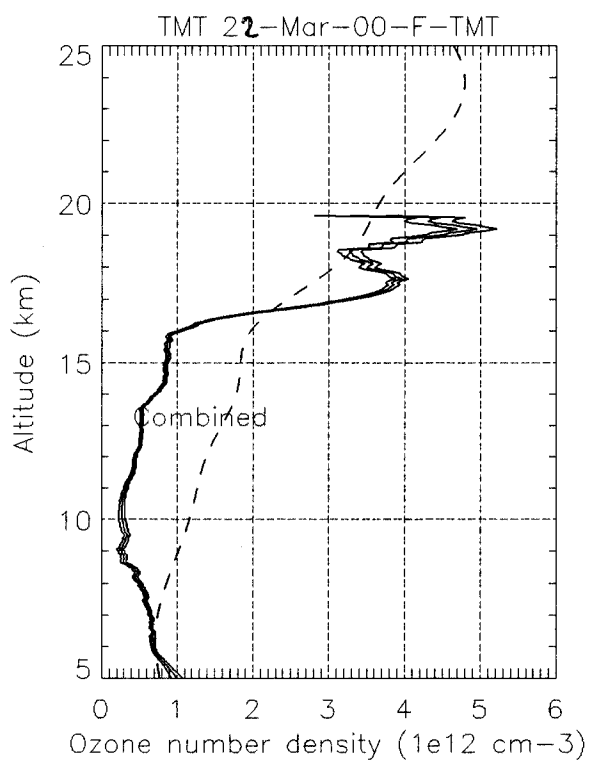
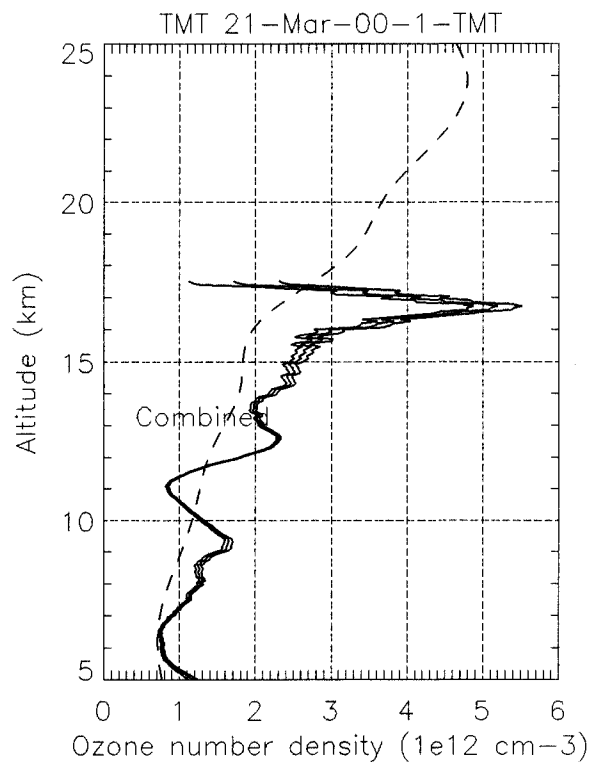
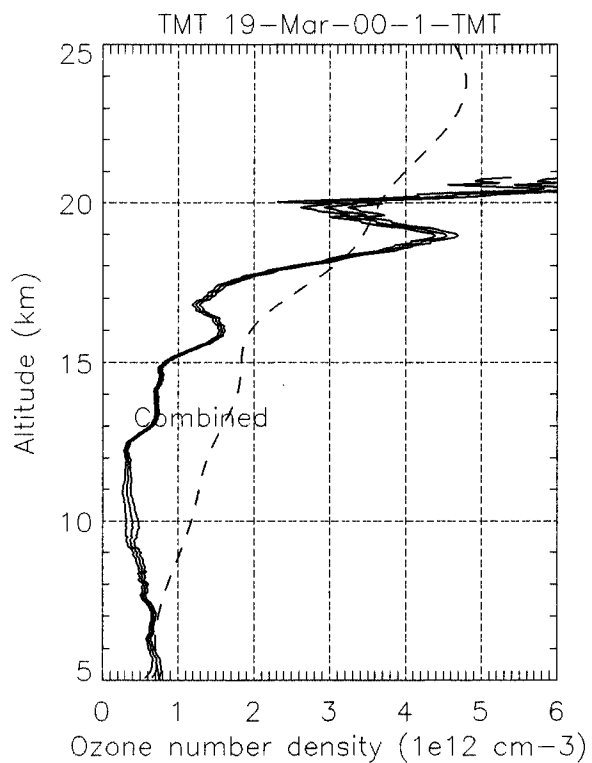


Figure 7